INFLUENCE OF UNGULATES ON THE FORESTS AND SCRUBLANDS OF SOUTH WESTLAND

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(Received for publication 29 November 1971)

ABSTRACT

The composition and structure of the forests and scrublands of South Westland were recorded at 834 sample points. The vegetation at each was classified into associations using a combination of Sorensen's "k" index of similarity, and a multi-linkage cluster analysis. The associations were related to habitat and the distribution of each determined.

Fourteen associations of which 10 were subclimax in nature were recognised; one included all the sub-alpine scrub, three were in high altitude silver beech forest, three were in mid altitude silver and mountain beech forest, and three were in low altitude silver beech forest. Four seral forest associations were recognised. These were variously dominated by lacebark, **Olearia** species, fuchsia, wineberry, kamahi, and pate.

The influence of red deer on the forests and scrublands was examined. Stand structure was used to determine the degree of modification and the susceptibility of the vegetation to damage from browsing. Browse indices were used to determine current ungulate use.

The associations most susceptible to damage by red deer were shown to be the seral ones and the most susceptible catchments, the Turnbull, the Waipara, and the upper Arawata. The associations which have been most modified by red deer are those at low altitudes, especially in the Waiatoto catchment, and the least modified are those at high altitudes, particularly in the lower Arawata. Present use of the forests and scrublands is most pronounced in seral areas and on the mid and lower-mid slopes. It is least at high altitudes, in the sub-alpine scrub and upper forest, and in the vicinity of the low level terraces. The catchments currently receiving the greatest use are the Arawata and upper Waiatoto, while those receiving least use are the Turnbull and Okuru.

INTRODUCTION

A reconnaissance survey of South Westland was carried out during the summer of 1970-71 by staff of the Forest and Range Experiment Station. The purpose was four-fold: to evaluate and describe the composition, structure, and habitat of the forest and scrub associations; to determine past and present influence of browsing ungulates on them; to evaluate the influence of venison hunting by helicopters and foot shooters on the condition of the forests and scrublands; and to establish a series of permanent reference points to permit measurement of future changes in the vegetation.

The area studied lies between the main divide and the seaward side of the Alpine Fault. It is bounded in the west by the Olivine Range and in the north by the Marks Range (Fig. 1). The total area is approximately 157 828 ha of which slightly over half supports a forest and scrub cover.

Technique

A total of 834 sociological descriptions of forest and scrub stands throughout the survey area form the basis of the present paper. A further 20 permanent plots will form datum points to aid in interpretation of future changes in the vegetation. Seven hundred and twenty-six of the sociological descriptions or temporary plots were located at slope intervals of 135 m along 62 altitudinal transects (plot lines on Fig. 1). The remaining 108 temporary plots were sited in off-line stations in representative stands of minor forests and scrub associations rarely sampled by on-line plots in the area.

Apart from the total number of transects and plots, the experimental layout, recordings made at plot sites, and methods of analysis are, with several minor exceptions, identical to those described in the paper on the north-west Fiordland survey (Wardle *et al.*, 1971). Thus the 834 sociological descriptions were reduced to 14 associations using a numerical procedure. In addition, the total area was divided into six more-or-less equal sized units (Fig. 2) in each of which the percentage areas occupied by the forest and scrub associations was calculated from the random on-line plot frequencies.

The changes in field technique and analysis are described below.

1. *Susceptibility of associations:* In the past the calculation of susceptibility of associations has been based on the following expression:

$$\text{susceptibility of association} = \frac{\Sigma\,(\text{IR} \times \text{SR})}{\Sigma\,\text{IR}}$$

where IR = importance rating of species,
and SR = susceptibility rating of same species.

However, in severely modified forest highly susceptible species could have a very high SR (up to ∞) and consequently could have a disproportionate effect on the susceptibility of the association as a whole. The expression for calculating the susceptibility of the associations has thus been modified to the form:

$$\text{susceptibility of association} = \frac{\Sigma\,\text{IR}}{\Sigma\,(\text{IR} \times \frac{1}{\text{SR}})}$$

In this form, a species cannot exert an influence disproportionate to its relative frequency.

In addition, any species with a susceptibility rating of < 1.00 has arbitrarily been assigned a susceptibility rating of 1.00 since this is the theoretical level of minimum ungulate influence. Large departures from this minimum arbitrary value are not common and are usually related to unusual growth forms, e.g., *Phormium colensoi* where close examination of the main plant clump (which is usually in the 0.30-1.83 m category) is necessary to separate out tillers in the < 0.3 m category.

2. *Degree of modification (indicating history of utilisation):* Originally 12 indicator

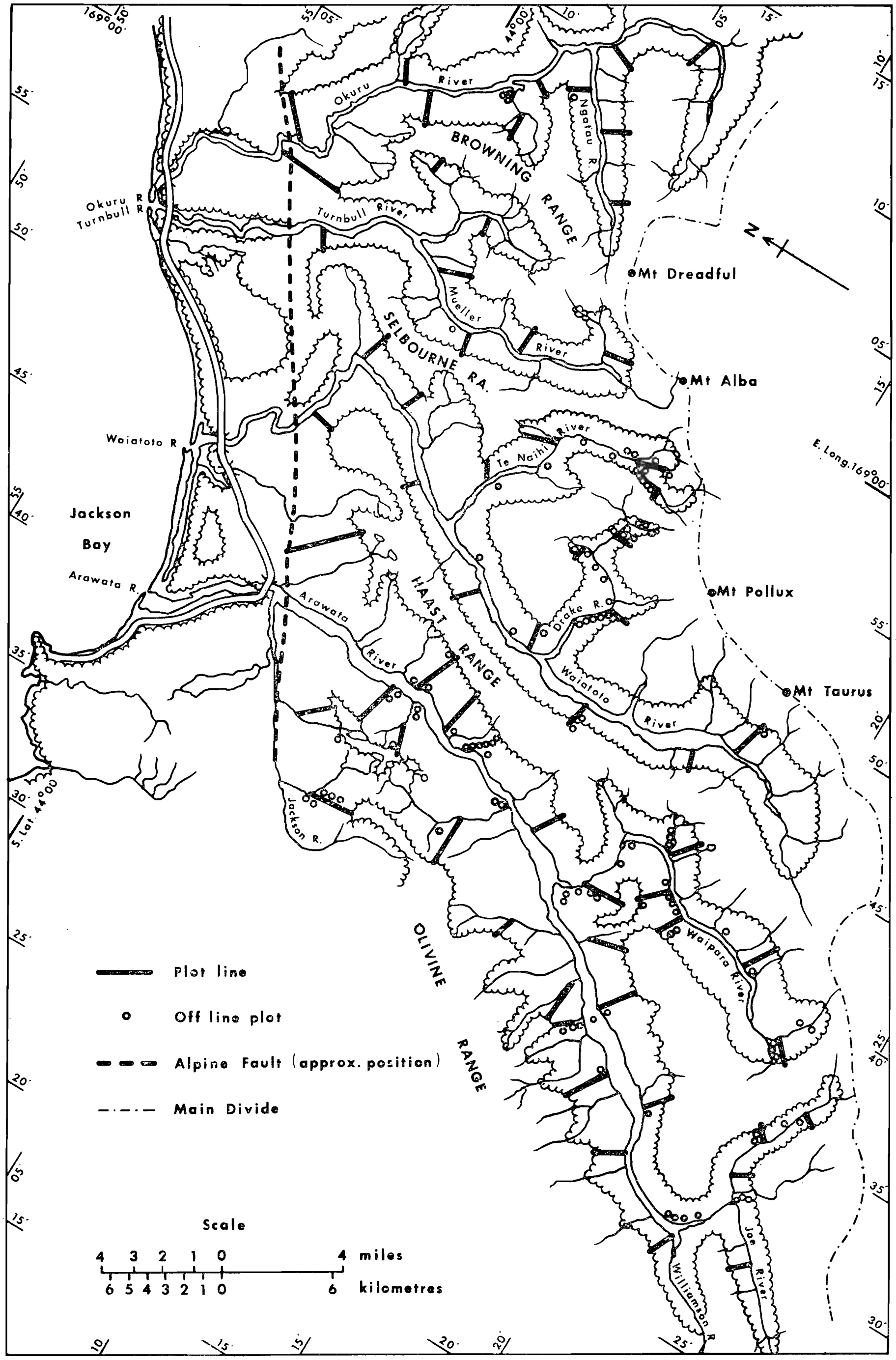

FIG. 1—Map of survey area showing line and plot positions.

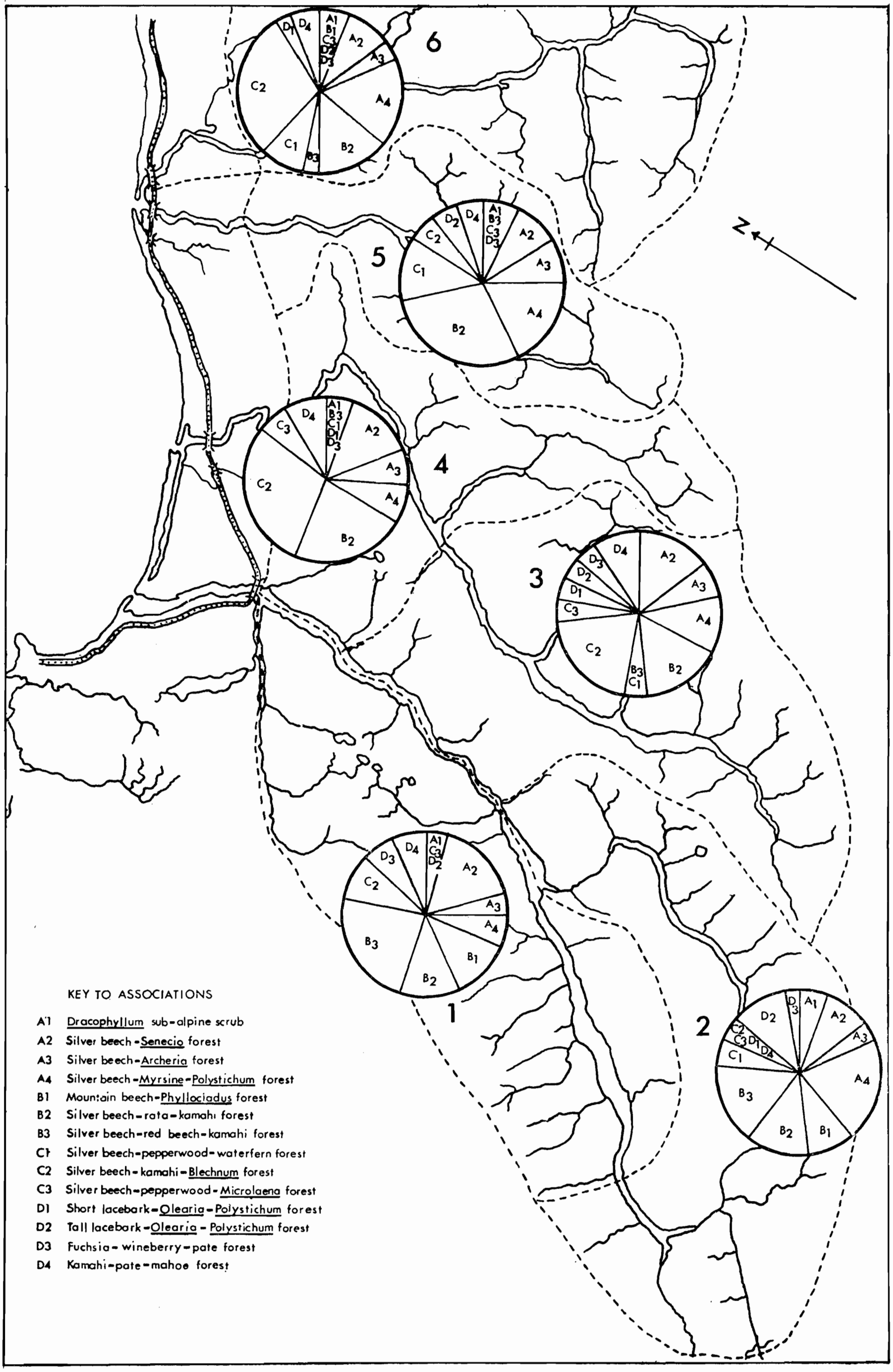

FIG. 2—Map of survey area showing block boundaries and the distribution of the forest and scrubland associations.

species were used. This has been extended to include 24 species comprising 12 shrub and large herb, and 12 tree species. The requirements for indicator species have been modified, to include those with the highest specific frequency as well as the highest susceptibility ratings.

Description of the Survey Area

The survey area is generally a deeply dissected upland separated from coastal terraces and farmland by the Alpine Fault which runs more or less parallel to, and 16-24 km seawards of the main divide. The region to the east of the fault line is characterised by high ridges and deep, steep-sided slopes, particularly towards the heads of the valleys. The frontal hills tend to be less steep sided, with rounded, ice-worn, tops. At the fault line the ridges are more than 1219 m high, and increase in altitude to a maximum of 3036 m (Mt. Aspiring) in the south-west corner of the survey area. From north to south the area is drained by the east-west tending Okuru and Turnbull rivers, and the south-north tending Waiatoto, Waipara, and Arawata rivers. Tributaries often join the main streams over waterfalls or across steeply inclined fans.

The highest peaks are grouped in the south-west at the heads of the Arawata and Waiatoto rivers. They include Mt. Edwards (2646 m), Mt. Aspiring (3036 m), Glacier Dome (2380 m), and Mt. Pollux (2542 m). Northwards along this main divide the major peaks become less outstanding.

In the Pleistocene the area was subjected to intense glaciation which moulded the landscape to its present form (Fig. 3). Glaciers and icefields at present occupy the

FIG. 3—The lower Waiatoto valley taken from the vicinity of the confluence of the Drake tributary. Note the typically glacial-sculptured landscape.

heads of most valleys. The more prominent glaciers are grouped around Mt. Aspiring and drain into the Waipara and Waiatoto rivers. These include the Bonar, Iso, Therma, and Volta Glaciers. Part of the Olivine Ice Plateau drains through the Andy Glacier into a tributary of the Arawata River, whilst further north the Pickelhaube and Axius Glaciers drain into the Drake and Te Naihi tributaries of the Waiatoto.

The rock type is predominantly quartz-feldspathic schist (garnet and oligoclase zones). It tends to be biotite bearing and becomes weakly foliated towards the main divide. There are extensive areas of gravel, sand, silt, and fan and slip debris, derived from the Hawera series on the present river terraces (Mutch and McKellar, 1965).

Skeletal forest soils cover all the steep hill land. They are generally shallow, infertile, and consist mainly of freshly weathered soil, disintegrating rock fragments from the parent schists and gneisses, and some decomposing plant remains. They are predominantly podzolic and belong to the Lewis, Haast, and McKerrow-Resolution series (New Zealand Soil Bureau, 1950, 1968).

The area lies within the zone of prevailing westerly winds with moisture laden winds from the Tasman Sea causing heavy precipitation and mist when they are forced to rise over the mountain ranges. Precipitation is heavy throughout the year but tends to be greatest in the summer months. In winter much of the precipitation at higher altitudes falls as snow. The nearest climate stations are at Haast, Paringa, and Franz Joseph. The mean annual long-term precipitation for these stations (1921-1950) is 3637, 5740, and 5070 mm respectively (N.Z. Meteorological Service, 1969). Rain falls on about 170 to 200 days annually. There are no existing climate stations or rain gauges in the vicinity of the main divide but it is probable that rainfall increases towards the mailn divide where it may well be in excess of 5080 mm per annum.

The survey area has been divided into six blocks, namely 1, Lower Arawata; 2, Upper Arawata-Waipara; 3, Upper Waiatoto; 4, Lower Waiatoto; 5, the Turnbull; and 6, the Okuru. This simplifies the comparison of forest and scrub composition and condition between catchments. The boundaries of each block are shown on Fig. 2.

DESCRIPTION OF THE FORESTS AND SCRUBLANDS

There have been no comprehensive descriptions of the botany and ecology of the South Westland forests. The first general descriptions of the vegetation were made by Douglas in the early 1900s. Cockayne (1928) gives a brief floristic description of his "Western District" and records a total flora of 755 species, including some local endemics. Holloway (1954) has treated the area in more detail. The following general description of the forests is largely a precis of the relevant parts of his paper but it has been brought up to date with information resulting from the present survey.

The forests on the foothills abutting the coastal lowlands are varied in character, ranging from pure silver beech* (*Nothofagus menziesii*) forest, through kamahi (*Weinmannia racemosa*), southern rata (*Metrosideros umbellata*), rimu (*Dacrydium cupressinum*), kamahi-rata, beech-podocarp to Hall's totara (*Podocarpus hallii*) — mountain cedar (*Libocedrus bidwillii*). There is little pattern in the distribution of these

* Botanical names used in this paper are according to Zotov (1963) for the grass sub-family **Arundinoideae**, Cheeseman (1925) for the remainder of the indigenous monocotyledons, Philipson (1965) for the genera of the **Araliaceae**, and Allan (1961) for all remaining species.

forest types. The inland forests are largely dominated by silver beech and silver beech admixtures with kamahi. Red beech (*Nothofagus fusca*), and mountain beech (*Nothofagus solandri* var. *cliffortioides*) both occur but are restricted to the Arawata valley and its tributaries. Red beech does become important, generally in admixture with silver beech, above the Waipara confluence. Mountain beech is very localised in distribution. It was seen at high altitudes at four sites: on shallow and infertile soils in the upper Arawata near the confluence with the Joe; in the vicinity, and some distance upstream, of the Arawata-Waipara confluence; and in the Jackson and Williamson tributaries of the Arawata River. Elsewhere it is restricted to occasional remnant bog stands in the lower Arawata valley where it may be associated with silver pine (*Dacrydium colensoi*) and mountain cedar. Records of mountain beech from the head of the Waiatoto valley (Wardle, 1970, p. 527) have not been substantiated on this survey.

The sub-alpine scrub zone varies in depth, tending to be most pronounced closest to the coast. It is usually dominated by *Dracophyllum* species but other species such as leatherwood (*Olearia colensoi*) may dominate locally.

In the present study 14 associations have been recognised. Further minor associations do undoubtedly exist, particularly in the vicinity of swamps and the coastal lowlands. The sampling system however has largely ignored these since the primary purpose of the survey was to sample the hill forest.

The 14 associations are listed below:

A1 *Dracophyllum* sub-alpine scrub
A2 Silver beech-*Senecio* forest
A3 Silver beech-*Archeria* forest
A4 Silver beech-*Myrsine-Polystichum* forest

B1 Mountain beech-*Phyllocladus* forest
B2 Silver beech-rata-kamahi forest
B3 Silver beech-red beech-kamahi forest

C1 Silver beech-pepperwood-waterfern forest
C2 Silver beech-kamahi-*Blechnum* forest
C3 Silver beech-pepperwood-*Microlaena* forest

D1 Short lacebark-*Olearia-Polystichum* forest
D2 Tall lacebark-*Olearia-Polystichum* forest
D3 Fuchsia-wineberry-pate forest
D4 Kamahi-pate-mahoe forest.

The composition, structure, and habitat of each are described below. The percent frequency of the species of major importance is given in Table 1, and tier densities and ground cover percentages in Table 2.

A1 — *Dracophyllum* sub-alpine scrub

Dracophyllum sub-alpine scrub occurs throughout the survey area but forms only a minor proportion of the total forest and scrub area. It occupies a belt above timberline

TABLE 1—The percent frequency of the major species for each association

SPECIES	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	D4
Acaena anserinifolia		1	2								17	38	6	
Anisotome haastii	40	5	2								29	2		
Archeria traversii	26	48	82	16	75	12	3	2			23	10		
Aristotelia fruticosa	13	7	10	4	2			7			52	78	6	1
Aristotelia serrata				17		4	19	32	10	32		6	86	49
Asplenium bulbiferum							8	5	24	45			51	87
Asplenium flaccidum		30	37	67	25	70	55	72	90	91		2	48	65
Astelia cockaynei	66	81	52	53	65	60	56	30	26	10	35	8	27	30
Blechnum capense	6	3	22	11	15	39	44		21	13	23	2	17	14
Blechnum discolor			2	14	15	78	92	40	93	21			27	41
Blechnum fluviatile		13	7	69	2	23	35	85	36	70	11	4	86	69
Blechnum lanceolatum				1		5	1	2	6	18			6	30
Blechnum minus	20	30	42	71	60	78	70	60	52	27	17	6	24	14
Blechnum penna-marina	13	7	7	14	2		1	37		10	41	65	3	
Cardamine debilis		3		7			3	15	4	21	5	55	20	10
Carmichaelia grandiflora		2									47	2	3	
Carpodetus serratus				17		22	44	37	57	54	5		93	70
Celmisia walkeri	60	5	7								17			
Chionochloa conspicua	13	4	17	3		1	1				58	12		
Chionochloa crassiuscula	33				5						5			
Chionochloa pallens	46	13	15		7	1					17	4		
Coprosma astonii		89	62	98	20	66	76	55	12	8	29	57	65	5
Coprosma australis			2			12	1	2	6	2			3	3
Coprosma cheesemanii	40	1									5	4	6	
Coprosma ciliata		34	2	75	2	23	24	75	15	40	23	65	41	7
Coprosma colensoi	6	18	50	30	57	61	19	15	17	5		2	10	7
Coprosma foetidissima	6	45	92	70	92	94	96	25	64	27			48	34
Coprosma lucida					10	8	32		9	2			6	14
Coprosma parviflora	20	6	5	2			3	7	6	5	17	34	17	
Coprosma pseudocuneata	73	96	90	54	85	29	15	2		2	47	21	6	
Coprosma rhamnoides		2		2		17	52	20	55	72		2	10	25
Coprosma rotundifolia			2				5	17	24	94			10	40
Coprosma rugosa	6	2	2					2			58	31	3	
Coprosma serrulata	40	2	5		2						11	2		
Cyathea colensoi		13	5	28	2	18	5	5						
Cyathea smithii		1	2	24	7	43	79	37	93	91			51	100
Dacrydium biforme	26	2	20		35									
Dacrydium cupressinum					5	6	12		29	27				9
Dicksonia squarrosa						3	8	7	41	32				30
Dracophyllum longifolium	53	24	50	4	25	4					70	21	3	
Dracophyllum menziesii	53	3	2		5						17			
Dracophyllum traversii	20	25	42	8	10	2		2			23	2		
Dracophyllum uniflorum	86	5			10						41	2		

TABLE 1 (continued)

SPECIES	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	D4
Elaeocarpus hookerianus					27	8	7	2	7	18				1
Enargea parviflora			5	2	55	7	6	15	5					
Epilobium linnaeoides		2		6				5		5	11	44	27	3
Forstera sedifolia	46	2	5								5			
Fuchsia excorticata		1	2	50	2	12	37	70	31	70	5	17	100	69
Gaultheria depressa	46	11	15		42						29	2		
Grammitis billardieri		29	30	50	62	80	85	75	77	43	11	4	20	32
Griselinia littoralis		37	62	99	75	96	100	92	90	94	23	31	86	74
Hebe odora	40	3	2								29	2		
Hebe salicifolia		7		6								36		
Hebe subalpina	13	4	2								47	21		
Hedycarya arborea						1	6		31	18			32	
Helichrysum bellidioides	6	1									70	6	3	
Histiopteris incisa		1	2	10		4	15	35	14	10		2	31	14
Hoheria glabrata	26	38	7	53	5		15	55		37	70	100	82	20
Hymenophyllum flabellatum				1	2	19	6	5	40	18			10	14
Hymenophyllum multifidum	60	86	75	57	75	56	15	60	15	5	23	17	6	3
Hypolepis millefolium		13	2	28		2	3	62	12	18	29	85	20	12
Libertia pulchella		1		1	50	9	3	2				2		
Libocedrus bidwillii		3	12	6	15	2	1	2						
Melicytus ramiflorus						3	10	2	37	21			13	87
Metrosideros diffusa						9	55	7	87	51			27	76
Metrosideros umbellata	13	1	57	17	75	77	6	5	28		17		3	16
Microlaena avenacea		1	5	10		17	24	45	28	78			17	12
Muehlenbeckia australis				3			15	7	8	37		10	62	54
Myrsine australis						4	16	2	16	5				12
Myrsine divaricata		56	57	74	65	35	15	45	15	48	23	59	10	1
Myrsine nummularia	46	10	7		2						11	2		
Neomyrtus pedunculata				1	10	9	14	12	17	48			3	1
Nertera depressa		5		18		12	8	35	35	32		10	24	29
Nertera dichondraefolia		5	5	73	10	42	94	82	78	89	5	8	68	40
Nothofagus cliffortioides	6	4		2	92	3	1							
Nothofagus fusca				5	17	9	80	17	4	21			37	3
Nothofagus menziesii	33	94	87	96	70	96	88	100	94	86	17	21	68	49
Olearia avicenniaefolia				2							41			
Olearia colensoi	40	18	35	6	2			2		2	29	8	3	
Olearia ilicifolia	20	20		22			1	17			70	85	37	1
Olearia lacunosa	6	12	5	4							35	2		
Olearia nummularifolia	33	2	2								52	36		
Oxalis lactea	6	4		2				10			17	38	6	
Pennantia corymbosa								5	6	40			6	41
Phormium colensoi	73	35	57	10	5	10					88	12	6	1
Phyllocladus alpinus	53	9	37	2	95	22	8				11	10		

TABLE 1 (continued)

SPECIES	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	D4
Phymatodes diversifolium		1	10	17	5	33	53	52	85	89	11	4	72	83
Pittosporum colensoi				2		3	2	2	14	8			20	7
Poa colensoi	40	4	7	3			1				64	14		
Podocarpus ferrugineus					5	20	34	5	45	64				16
Podocarpus hallii		2	15	16	75	65	52	7	34	29		4	10	17
Podocarpus nivalis	40	10	4		2						17	14		
Polystichum vestitum	13	56	5	84		18	30	77	41	91	100	97	100	72
Pratia angulata	6	12		26		2		30		8	17	29	10	3
Pseudopanax anomalum				2	5		7	27	7	51			6	1
Pseudopanax arboreum						1			14					9
Pseudopanax colensoi	46	65	67	37	72	50	50	7	34	8	58	23	20	14
Pseudopanax crassifolium	6	4	25	11	10	60	88	55	81	64			27	3
Pseudopanax edgerleyi						1	14		10	10				1
Pseudopanax lineare		24	70	45	87	32	11		2	2	23		3	
Pseudopanax simplex		47	72	91	87	93	94	67	52	40		2	44	14
Pseudowintera colorata		4	5	66	7	52	92	92	78	94		6	93	61
Ranunculus hirtus		2	2	17				30		5	29	85	17	1
Rubus cissoides				36		7	43	20	9	18	5		68	27
Rumohra adiantiformis				1		4	23	2	41	27				40
Rumohra hispida							1	2	30	8			6	21
Schefflera digitata				6		7	33	30	55	64			82	100
Senecio bennettii	26	77	72	33	27	10					35	23	6	
Todea superba		2		32	2	15	37	42	20	48			13	20
Uncinia filiformis	6	83	60	76	17	62	20	32	7	8		21	13	3
Uncinia rupestris		17	10	26	27	20	8	45	14	16	17	12	13	3
Uncinia uncinata		2		4	2	4		5	13	32	11	2		10
Viola filicaulis	6	1		8			1	25			41	36	6	
Weimannia racemosa			15	20	57	94	93	20	100	67			41	92

TABLE 2—Stand densities. The mean density of each tier in each association is given. This has been determined by use of ground cover percentages for the < 305 mm tier and by a tier density index for the remaining four tiers. The index is calculated by the following formula:

$$\frac{3\text{ (f dense)} + 2\text{ (f mod.)} + 1\text{ (f open)}}{3\text{ (total no. of plots)}} \times \frac{100}{1}$$

where f = frequency of plots with dense, medium, and open tiers

TIER	Metres		A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	D4
			ASSOCIATION													
Tier Density Index	T1 (12+)		0	20	12	43	31	51	59	61	58	58	0	0	25	26
	T2 (4.6-12)		4	48	46	60	66	62	66	50	64	61	9	28	64	70
	T3 (1.8-4.6)		29	72	76	60	80	61	72	54	53	63	52	59	72	58
	T4 (0.3-1.8)		85	75	72	54	70	58	66	53	66	59	88	80	59	52
Percent Ground Cover	T5 (<0.3)	M	15	36	34	38	56	34	38	43	27	36	14	24	37	31
		L	22	31	35	35	25	40	41	25	40	34	19	21	24	35
		V	50	26	20	17	16	16	16	24	23	23	52	45	23	17
		B	6	4	5	4	0	5	2	4	4	5	2	3	7	3
		R	7	3	6	6	3	5	3	3	6	2	13	7	9	14

(Fig. 4) which varies from a few metres to 150 m in depth, tending to be most extensive where the timberline is depressed and on eastern facing slopes. It has a mean altitude of 1006 m (Fig. 5) and ranges from 823 to 1189 m. It is variable in composition and, as it occurs on fairly stable soils, is regarded as being sub-climax in status.

The shrub canopy has a mean top height of 4.6 m (Fig. 6) and is fairly open (Table 2). It is dominated by *Dracophyllum uniflorum,* and *Coprosma pseudocuneata. Dracophyllum longifolium, D. menziesii,* and *Pseudopanax colensoi* are also common and other locally important species are leatherwood, *Hebe odora, Podocarpus nivalis,* and *Phyllocladus alpinus.* Many herbaceous and small woody species are present. Dominant among these are usually *Astelia cockaynei, Phormium colensoi, Hymenophyllum* species and *Celmisia walkeri,* but in the inter-shrub spaces, *Poa colensoi, Forstera sedifolia, Gaultheria depressa,* and *Coprosma cheesemannii* may also be important.

A2 — Silver beech-*Senecio* forest

This is a major association and forms over 10% of the total forest and scrub cover in the survey area (Fig. 2). It is the main association forming the timberline stands. The altitude of the timberline ranges from 850 to 1160 m dependent on local physiographic features. The mean altitude is 1006 m, though it tends to be slightly higher than this downstream and slightly lower in the upstream reaches of the main rivers. The association has a mean altitude of 945 m and ranges from 730 to 1160 m. It is the least complex association in the survey area (Fig. 7) with a mean of 17 vascular species per plot. The canopy is fairly open, reaches a mean top height of 12 m and is dominated entirely by silver beech. *Senecio bennettii* and occasionally broadleaf (*Griselinia littoralis),* lacebark (*Hoheria glabrata*) and *Pseudopanax simplex* form a moderately dense sub-canopy and there is a dense shrub understorey dominated by *Coprosma pseudocuneata* and *Coprosma astonii* and less often by *Myrsine divaricata* and *Pseudopanax colensoi.* The main ground cover species are *Hymenophyllum multifidum, Uncinia filiformis, Astelia cockaynei* and *Polystichum vestitum.*

A3 — Silver beech-*Archeria* forest

Silver beech-*Archeria* forest is moderately important throughout the survey area, forming about 5% of the total forest and scrub. It occurs over an altitudinal range from 600 to 1036 m with a mean altitude of 870 m. Silver beech-*Archeria* forest occasionally forms the timberline but more often forms a belt beneath the silver beech-*Senecio forest.* It tends to occupy steep spur sites (Table 3), where the soil is thin and parent rock often exposed, and also drier south-west facing slopes (Fig. 8).

The mean stand top height is 10.7 m, and the canopy which is usually fairly open is dominated by silver beech often associated with southern rata. There is a small-tree layer dominated by *Pseudopanax simplex, Senecio bennettii, Dracophyllum longifolium* and broadleaf. Locally, *Dracophyllum traversii* may be important. The shrub tier is fairly dense and is dominated by *Archeria traversii, Coprosma foetidissima, Coprosma pseudocuneata,* and to a lesser extent by *Coprosma astonii, Coprosma colensoi,* and *Myrsine divaricata.* Sometimes leatherwood may be important. The ground cover is mainly *Hymenophyllum multifidum, Astelia cockaynei, Phormium colensoi, Uncinia filiformis* and *Blechnum minus.*

FIG. 4—**Dracophyllum** sub-alpine scrub in the lower Arawata catchment. This scrub occupies a belt above timberline, which varies from a few metres to 150 m in width.

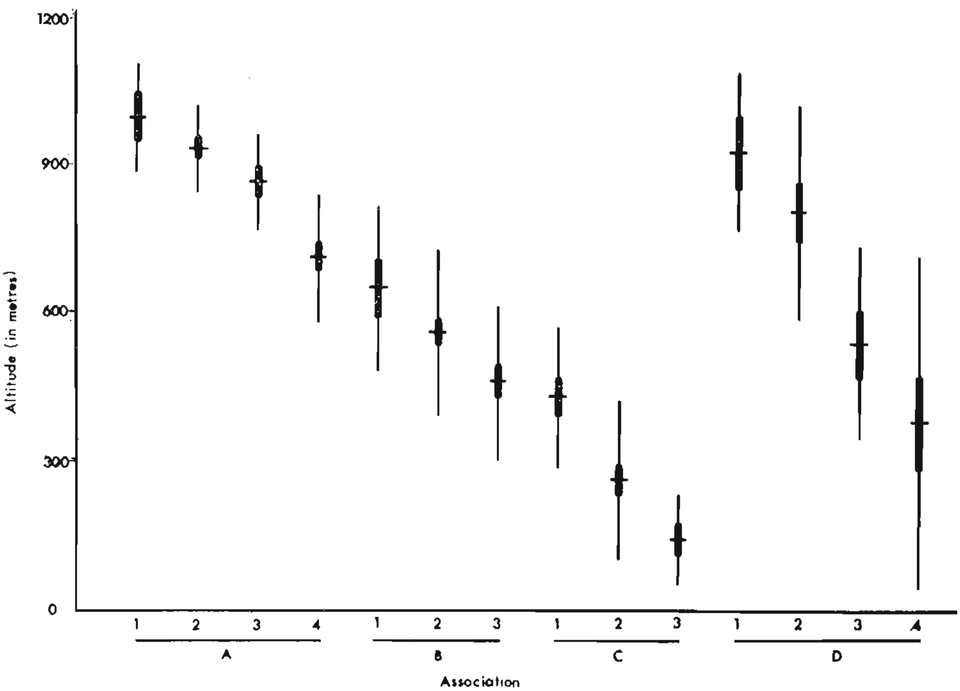

FIG. 5—Altitude. The mean, standard error (P = 0.05) and standard deviation for the plots in each association are given.

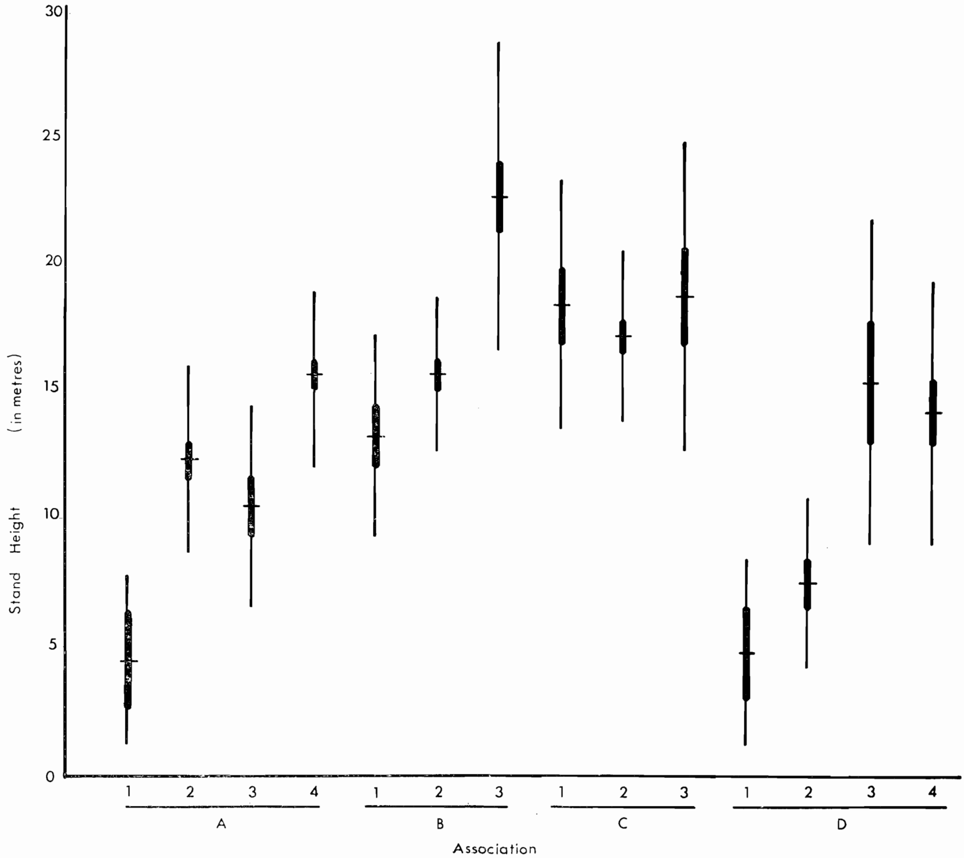

FIG. 6—Stand heights. The mean, standard error (P = 0.05), and standard deviation for each association are shown.

A4 — Silver beech-*Myrsine-Polystichum* forest

This major association forms about 12% of the total forest and scrub. It is most important in the north and in the upper reaches of the main rivers, especially in the upper Arawata where it is the main forest association. It occurs on the upper mid-slopes below A2 and A3 and the mean altitude is 716 m.

Silver beech is the only important large tree. It forms a fairly dense canopy with a mean top height of 16 m (Fig. 6). There is a prominent small-tree layer dominated by broadleaf, *Pseudopanax simplex,* fuchsia (*Fuchsia excorticata),* and lacebark. The understorey shrub tiers are fairly open and the main species are *Myrsine divaricata, Coprosma astonii, C. ciliata,* and to a lesser extent pepperwood (*Pseudowintera colorata*) (Fig. 9). The herbaceous ground cover is dominated by *Polystichum vestitum, Blechnum minus, B. fluviatile, Nertera dichondraefolia,* and *Uncinia filiformis.*

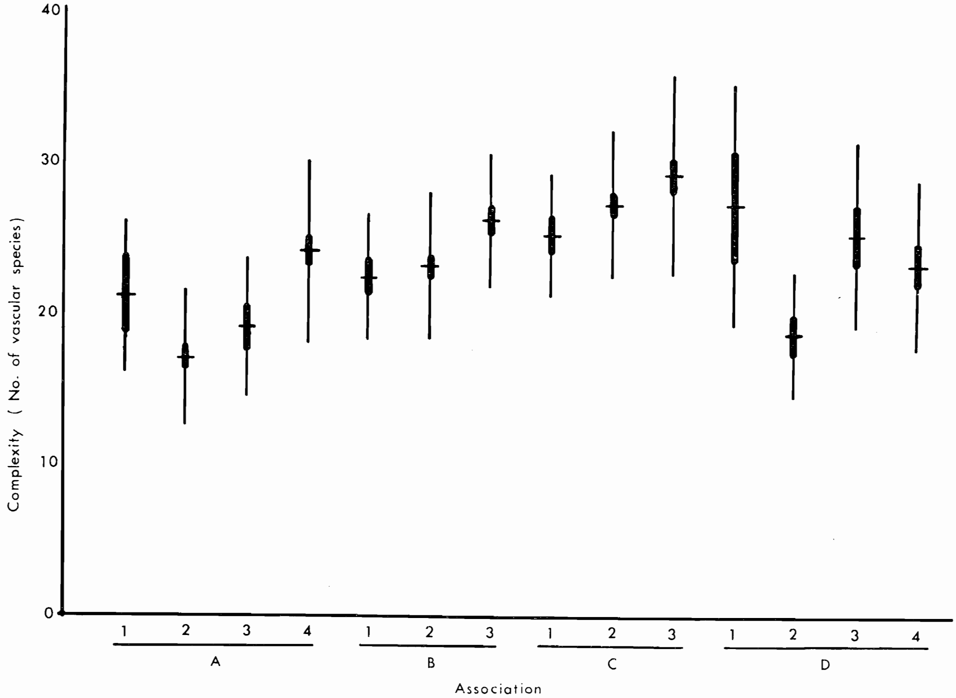

FIG. 7—Stand complexity. The mean, standard error (P = 0.05), and standard deviation for vascular plant species in each association are given.

TABLE 3—Soil depth, drainage, soil surface features, and physiography for each association. The drainage factor has been calculated by the following formula:

$$\frac{3\ (\text{f good}) + 2\ (\text{f mod.}) + 1\ (\text{f poor})}{3\ (\text{total no. of plots})} \times \frac{100}{1}$$

where f = frequency of plots with good, moderate, or poor drainage

SITE AND SOIL FACTORS	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	D4
	ASSOCIATION													
Mean soil depth (mm)	66	89	64	102	122	104	122	112	137	287	51	33	38	79
Drainage factor	98	98	100	96	82	97	97	93	94	82	98	94	95	92
% Plots with:														
Parent rock exposed	27	10	26	11	22	20	7	6	12	7	0	3	12	13
Loose rock exposed	73	60	63	76	45	61	58	77	67	36	82	84	92	94
mainly <300 mm	55	36	52	57	28	46	44	60	46	33	47	79	71	63
mainly >300 mm	18	24	11	19	17	15	14	17	21	3	35	5	21	31
No rock exposed	27	40	33	24	53	36	42	22	32	63	18	16	8	6
% Plots on:														
Face sites	93	62	43	78	70	62	80	53	65	27	83	74	82	74
Spur sites	7	32	57	13	27	30	13	0	9	0	11	2	3	2
Gully sites	0	5	0	3	3	4	3	7	3	0	0	13	11	21
Terrace sites	0	1	0	6	0	4	4	40	23	73	6	11	4	3

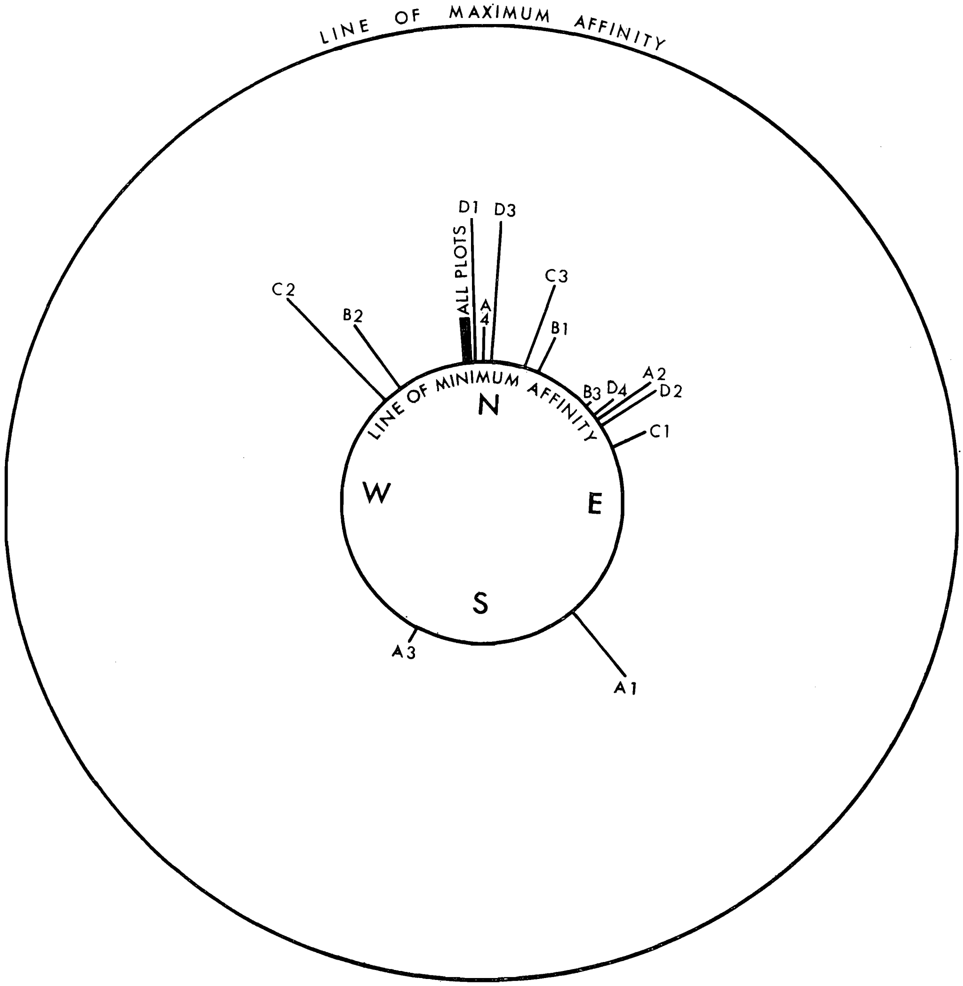

FIG. 8—Mean aspect, calculated from components for each association. The length of the line illustrating the aspect represents the strength of the components in that direction and is calculated from $\dfrac{(\Sigma \sin \theta)^2 + (\Sigma \cos \theta)^2}{\text{number of plots}}$ where θ is aspect in degrees.

B1 — Mountain beech-*Phyllocladus* forest

This association is virtually restricted to the Arawata valley where it is important in four areas: the upper Arawata near the confluence with the Joe; in the vicinity of and some distance upstream of the Arawata-Waipara confluence; and in the Jackson and Williamson tributaries of the Arawata River. It predominates on sites with poor drainage and on sites where the parent rock is slow weathering. It occurs over a fairly wide range of altitude but the mean is 655 m.

FIG. 9—Silver beech-**Myrsine-Polystichum** forest in the Drake tributary of the Waiatoto. The understorey has been browsed out by red deer.

The canopy has a mean top height of 13.4 m and the dominant species are mountain beech, southern rata, and Hall's totara. Silver beech and kamahi are sometimes associated and on some sites, pink pine (*Dacrydium biforme*), mountain cedar and pokaka (*Elaeocarpus hookerianus*) may co-dominate. There is a sub-canopy of small trees such as broadleaf,*Pseudopanax colensoi, P. lineare,* and *P. simplex*. The shrub tier is dense and dominated by *Phyllocladus alpinus, Archeria traversii, Coprosma foetidissima* and *C. pseudocuneata. Coprosma colensoi* and *Myrsine divaricata* may also be important. The ground cover is predominantly of moss and *Hymenophyllum* ferns with other small herbs such as *Enargea parviflora, Blechnum minus,* and *Libertia pulchella.*

B2 — Silver beech-rata-kamahi forest

This association is the most important forest on the mid-slopes, especially on steep faces and spurs. It usually forms a belt under A4 and has a mean altitude of 564 m. It accounts for about 15% of the forest and scrub of the total survey area but is more important in the northern than in the southern catchments. In the Turnbull, approximately a third of the forest and scrub is made up of this association.

The canopy, which is dominated by silver beech, rata, kamahi, and Hall's totara, is fairly dense and has a mean top height of 16 m. The sub-canopy mainly comprises broadleaf, *Pseudopanax simplex* and to a lesser extent lancewood (*P. crassifolium*), *P. colensoi,* and *Cyathea smithii.* The shrub understorey is dense and dominated by *Coprosma foetidissima, C. colensoi, C. astonii,* and pepperwood. *Blechnum discolor, B. minus* and *B. capense* form a dense fern layer and the ground cover is predominantly litter with some *Uncinia filiformis* and *Nertera dichondraefolia.*

B3 — Silver beech-red beech-kamahi forest

This association also occupies the mid-slopes with a mean altitude of 457 m, but whereas B2 mostly occurs to the north of the survey area, this association is almost entirely confined to the Arawata catchment in the south. It forms about a quarter of the total forest and scrub in the lower Arawata, but less than 10% for the total survey area.

It is the tallest association and the canopy, which is composed of red beech with some miro (*Podocarpus ferrugineus*), is 23 m high. There is a well developed sub-canopy of silver beech, kamahi, and Hall's totara and a small-tree layer of broadleaf, lancewood, *Pseudopanax simplex,* and *Cyathea smithii.* Putaputaweta (*Carpodetus serratus*), fuchsia, and pate (*Schefflera digitata*) may also be present. The shrub tiers are composed of pepperwood, *Coprosma foetidissima,* and *C. astonii,* with some *C. rhamnoides* and *C. lucida.* There is a dense, tall fern layer of *Blechnum discolor* and *B. capense.* The ground cover is predominantly litter but *Blechnum minus, Nertera dichondraefolia,* and *Metrosideros diffusa* are common.

C1 — Silver beech-pepperwood-waterfern forest

This association is a relatively minor one and forms less than 5% of the total forest and scrub area. It is scattered throughout but predominates in the north. It occurs at low altitudes, with a mean of 427 m and is most often found on terraces or gentle slopes (Fig. 10, Table 3) where soil drainage is good.

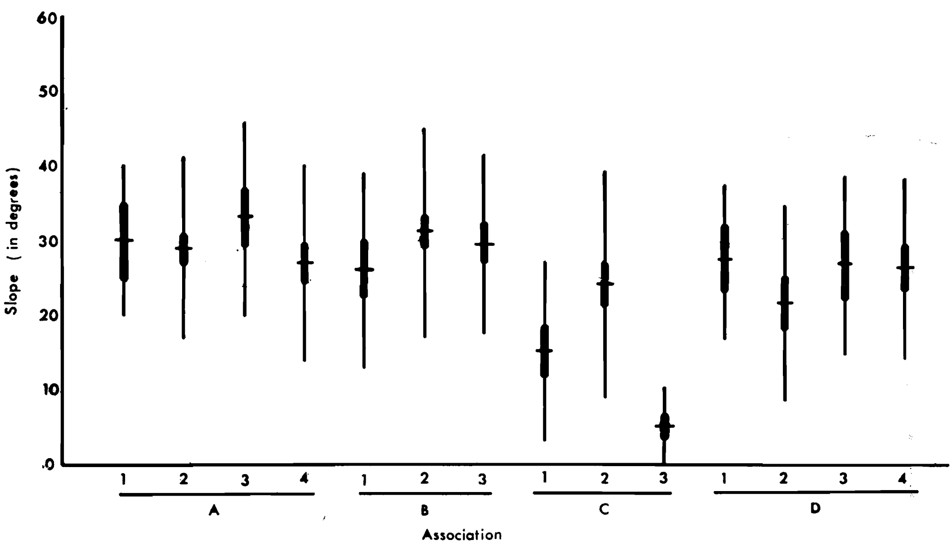

FIG. 10—Slope. The mean, standard error (P = 0.05) and standard deviation for the plots in each association are given.

The canopy, which is fairly dense, has a mean top height of 19 m and is dominated by silver beech. There is a sub-canopy in which the main species are fuchsia, broadleaf, lacebark, lancewood, and *Pseudopanax simplex,* and to a lesser extent wineberry (*Aristotelia serrata*), putaputaweta, *Cyathea smithii* and pate. The shrub understorey is generally fairly open and is mainly composed of *Coprosma ciliata, pepperwood,* and *Coprosma astonii.* The main ground cover species are *Polystichum vestitum, Blechnum fluviatile, Hypolepis millefolium, Histiopteris incisa, Nertera dichondraefolia,* and *Todea hymenophylloides.*

C2 — Silver beech-kamahi-*Blechnum* forest

This major forest association accounts for about 15% of the total forest and scrub in the survey area. It is particularly important in the Okuru and lower Waiatoto catchments, where in each case it forms about a third of the total forest cover. The mean altitude for the association is 274 m, and it is usually found on the well drained easier slopes and terraces where the soil is usually deep.

The canopy, which is moderately dense, has a mean top height of 17 m and is composed of kamahi and silver beech with frequent miro and Hall's totara. Underneath there is a small-tree layer dominated by the tree ferns *Cyathea smithii* and *Dicksonia squarrosa,* broadleaf, lancewood, and putaputaweta, with some pate, *Pseudopanax simplex,* pigeonwood (*Hedycarya arborea*) and mahoe (*Melicytus ramiflorus*). The main species in the shrub understorey, which is fairly open, are pepperwood, *Coprosma foetidissima* and *C. rhamnoides;* the herbaceous ground cover is *Blechnum discolor, B. minus, Nertera dichondraefolia,* and often also *Rumohra adiantiformis* and *R. hispida.*

C3 — Silver beech-pepperwood-*Microlaena* forest

Association C3 forms only about 4% of the total forest of the survey area. It almost invariably occurs on terrace sites at low alitudes. The mean altitude for this association is 152 m and the mean slope 5°. The soils are usually deep with a mean depth of 287 mm, and often poorly drained.

It is the most complex association in the survey area and has a mean of 29 vascular species per plot. The canopy which is moderately dense has a mean top height of 19 m and is composed of silver beech, miro, and kamahi. The sub-canopy is composed of fuchsia, broadleaf, putaputaweta, lancewood, and pate. The shrub understorey is fairly open and the main species are pepperwood, *Coprosma rhamnoides, C. rotundifolia,* and *Cyathea smithii* with some *Neomyrtus pedunculata* and *Pseudopanax anomalum.* The main species forming the understorey are *Microlaena avenacea, Blechnum fluviatile, Polystichum vestitum* and *Nertera dichondraefolia.* There is also some *Metrosideros diffusa, Asplenium bulbiferum, Uncinia uncinata* and *Todea superba.*

D1 — Short lacebark-*Olearia-Polystichum* forest

This association, although distributed throughout, forms less than 2% of the total forest and scrub of the survey area. It occurs at high altitudes with a mean of 930 m. It is ecotonal between forest and scrub and is seral in nature (Fig. 11), occurring on old talus slopes, especially those which are moderately steep. The soil under the stands is thin, with an average depth of 51 mm, and there is usually a large amount of broken rock exposed on the surface.

FIG. 11—Short lacebark-**Olearia-Polystichum** forest in the upper Te Naihi tributary of the Waiatoto catchment. This is a seral forest which occurs at high altitude in the vicinity of the timberline. It is usually relatively unmodified by deer.

The association is complex, with a mean of 27 vascular species per plot, most of which are shrubs or herbs. The canopy is open and has a mean height of about 5 m. It is dominated by lacebark, *Olearia ilicifolia,* and *Dracophyllum longifolium.* The shrub understorey is fairly open and is dominated by *Phormium colensoi, Aristotelia fruticosa, Chionochloa conspicua, Coprosma rugosa, Olearia nummularifolia,* pepperwood and *Carmichaelia grandiflora.* There is also some *Coprosma pseudocuneata, Dracophyllum uniflorum, Hebe subalpina, Olearia avicenniaefolia, O. lacunosa,* and leatherwood. The ground cover is dense and dominated by *Polystichum vestitum* but a number of small herb species such as *Viola filicaulis, Helichrysum bellidioides, Poa colensoi* and *Blechnum penna-marina* are also frequent.

D2 — Tall lacebark-*Olearia-Polystichum* forest

This is again a seral association which generally occurs at lower altitudes than D1. The mean altitude is 808 m. It is more important than D1 and forms around 5% of the total forest and scrub of the survey area. It occurs throughout but tends to be most important towards the heads of catchments. It occupies steep talus faces and gully sites. The soils are skeletal with a mean depth of 33 mm and in most cases there are quantities of small rock fragments scattered on the surface.

The canopy is open and has a mean top height of 7.6 m. It is dominated by lacebark often with *Olearia ilicifolia.* The shrub tier is also open and dominated by *Aristotelia fruticosa.* Other shrub species often present are *Coprosma astonii, C. ciliata, C. parviflora, C. rugosa, Hebe salicifolia,* and *Myrsine divaricata.* The ground cover is dense *Polystichum vestitum* and *Hypolepis millefolium.* A number of small herb and fern species often associated include *Ranunculus hirtus, Blechnum penna-marina, Cardamine debilis, Acaena anserinifolia, Epilobium linnaeoides, Oxalis lactea* and *Viola filicaulis.*

D3 — Fuchsia-wineberry-pate forest

This again is a seral association. It occurs throughout the survey area but forms only about 3% of the total forest and scrub. It generally occurs at lower altitudes than the previous two seral associations and the mean altitude is 550 m. It occupies old talus slopes where the soil is thin and usually covered with broken rock fragments. The mean soil depth is 38 mm.

The canopy is moderately dense, has a mean top height of 15.5 m and is dominated by wineberry, fuchsia, pate, and putaputaweta. Lacebark, broadleaf, and silver beech, and less often *Cyathea smithii,* pigeonwood, kamahi, red beech, and *Olearia ilicifolia* may also be important in the tree tiers. The shrub tiers are moderately dense and dominated by pepperwood, with some *Coprosma astonii, C. ciliata,* and *C. foetidissima.* There is a fairly open ground cover of herbaceous species which is dominated by *Polystichum vestitum, Blechnum fluviatile, Asplenium bulbiferum,* and *Histiopteris incisa.* The lianes *Muehlenbeckia australis* and *Rubus cissoides* are also important.

D4 — Kamahi-pate-mahoe forest

This association forms 6% of the total forest of the survey area. It is distributed throughout on moderate slopes and gully sites at mid to low alitudes. The mean altitude for the association is 381 m. It is predominantly seral in nature and occurs where there is loose rock debris. The mean soil depth is 79 mm.

The canopy, which is fairly dense, has a mean top height of about 14.3 m and is composed of kamahi, pate, and mahoe. Other less important tree species include broadleaf, putaputaweta, *Cyathea smithii,* fuchsia, wineberry, *Dicksonia squarrosa, Pennantia corymbosa,* and silver beech. The shrub understorey is fairly open. The dominant species here are pepperwood, *Coprosma foetidissima,* and *C. rotundifolia.* The herbaceous ground cover tier is also fairly open and is dominated by *Asplenium bulbiferum* and *Metrosideros diffusa.* Other species include *Polystichum vestitum, Blechnum fluviatile, B. lanceolatum, B. discolor, Nertera dichondraefolia* and *Rumohra adiantiformis.*

The 14 associations distinguished and described above have no hard and fast boundaries. Each grades into others to form clines. The description of the composition, structure, and habitat of each association above is in fact the description of the mean stand. The main two environmental influences relating to change from one association to another are altitudinal variation and site instability. The A, B, and C associations which are sub-climax in nature, have a distribution largely related to changes in altitude (Fig. 5), while the distribution of the D associations relates to a combination of instability of site and changes in altitude.

The A associations occur at high altitudes. A1 is a sub-alpine scrub community, but the remaining three are forest. The B associations occupy the mid slopes. With the exception of B1, the mountain beech-*Phyllocladus* forest, the distribution of which is largely governed by soil factors, the A and B associations fit into an altitudinal sequence (Fig. 5). Within this sequence, some, such as A3, silver beech-*Archeria* forest, tend to be associated with the drier spur sites (Table 3) while others are more related to the face slopes. The C associations occur at low altitudes and all are strongly affiliated with terrace sites. The four D associations are all seral in nature. D1, short lacebark-*Olearia-Polystichum* forest, occupies high altitude talus slopes and tends to be ecotonal between forest and scrub. D2 and D3 occur on mid altitude talus slopes and the lowest talus slopes support association D4, kamahi-pate-mahoe forest.

All the associations are complex in nature. The least complex is A2, silver beech-*Senecio* forest, which has a mean of 17 vascular species per plot. The most complex is C3, silver beech-pepperwood-*Microlaena* forest, with 29 species of vascular plants per plot. Generally there is a decrease in complexity with increasing altitude (Fig. 7), but there are exceptions. The sub-alpine scrub tends to be more complex than would be expected on the basis of the altitude it occupies while the seral communities tend to be less complex.

Stand height is usually greatest in the associations occupying the lowest altitudes but seral communities are shorter than the sub-climax counterparts (Fig. 6).

ANIMAL HISTORY

Except where otherwise stated, information on red deer (*Cervus elaphus*) and thar (*Hemitragus jemlahicus*) has been provided by C. Challies, on chamois (*Rupicapra rupicapra*) by R. Lambert, on opossums (*Trichosurus vulpecula*) by K. Tustin and C. Challies, and on other animals by K. Tustin.

Red deer colonised the survey area from liberations which took place near Lake Hawea in 1871 and near the head of Lake Wakatipu between 1903 and 1905. The present populations are largely derived from the Hawea liberation and the influence of the Wakatipu herd is restricted to the south and west. Breeding populations became established in the Okuru some time between 1920 and 1930 and in the Turnbull by about 1940. The Waiatoto was first colonised near the head around 1940 but not downstream until some years later. The heads of the Waipara and Arawata were both occupied by 1950 but the lower Arawata not until 10 yr later.

Chamois penetrated the area from east of the main divide. The first report, probably of a solitary male, was from the Therma glacier in 1939 (J. T. Holloway, pers. comm.). Breeding populations did not become established, however, until about 1945. Chamois were established near the main divide in the Turnbull, Waiatoto, and probably also the Okuru by 1945 and near the main divide in the Arawata between 1945 and 1950. The frontal hills in each catchment carried breeding populations about 10 yr after the headwaters.

Opossums are now present in South Westland as far south as the Paringa River, and also across the main divide in West Otago. Small breeding populations have recently become established in the headwaters of the Haast River, and also in the lower Haast valley (I. Rendal, pers. comm.). However, there are probably no breeding populations in the survey area although occasional animals have been reported since 1956. Hares (*Lepis europaeus*) are present in low numbers in the vicinity of Williamson

Flat in the Arawata valley and localised populations of rabbits (*Oryctolagus cuniculus*) occur in the lower terraces in the Okuru and Arawata valleys. However, opossums, hares, and rabbits are as yet of little significance in animal-plant inter-relationships in the forest and scrub of the survey area.

Domestic cattle (*Bos taurus*) have been present in varying numbers in all the main valleys for at least the last 60 yr. They have mainly been confined to the readily accessible lower valley flats.

Government hunting for red deer first commenced in South Westland, in the Haast River headwaters, in summer 1932-33. The first available records of Government hunting in the survey area was for the Okuru in 1947-48. Probably though, it was initiated some years previously. The Turnbull was first culled in 1951-52. Government hunting in these two catchments was carried out annually until the summer of 1956-57 but the operations were not extended to the Arawata or Waiatoto. The whole survey area has been shot over by trophy hunters, however, and the first party visited the Okuru in 1926. In 1960 Government sponsored private hunting occurred throughout the survey area.

Venison recovery shooting operations developed in the early 1960s and are still continuing. First recovery was from ground shooting, and part-resident shooters still occupy most of the main valleys. The Okuru and Turnbull are the two catchments which have received the greatest overall pressure from ground shooting. Helicopters have been used since summer 1964-65 through to the present time but the peak effect on the animal populations from this source was in 1967.

ANIMAL-PLANT INTER-RELATIONSHIPS

Susceptibility and Trend in Vegetation

(a) Individual Species

Many forest and scrubland species in the survey area show a tier gap which can be related to the presence of deer. Table 4 shows that 45 of the more important species have a susceptibility rating of greater than 1. In most cases this results from browsing pressure. The tier gap is more prounounced in the tree species than in the shrub and large herb species. This implies that regeneration of tree species is in most cases the most susceptible to browsing pressure. In some tree species such as broadleaf and mahoe, only one stand in each five examined with the species present, showed regeneration in the browse-susceptible 0.3-1.8 m tier. Even the major tree species in the area, kamahi and silver beech, show pronounced regeneration gaps.

Continued use by deer at the present rate would undoubtedly result in a degeneration of the forest on some sites, especially those where scrub-hardwood species such as broadleaf and mahoe dominate.

(b) Associations

It was mentioned above that the tree species in the survey area tend to be more susceptible to browsing pressure by deer, than the understorey shrub and tall herb species. Certainly the understorey in the 13 forest associations shows relatively low susceptibility (Fig. 12). The understorey susceptibility does tend to increase as the associations occupy progressively lower altitudinal belts (i.e., A2 through to C3 and D1 to D4). It also tends to be greater in the seral, D associations than in those that

TABLE 4—Susceptibility ratings and frequencies of the more important species

SPECIES	SR	FREQ.	SPECIES	SR	FREQ.
SHRUBS AND HERBS					
Asplenium bulbiferum	5.57	119	Olearia nummularifolia	0.70	34
Hebe salicifolia	3.20	40	Coprosma banksii	0.67	17
Gaultheria antipoda	2.00	26	Phormium colensoi	0.67	117
Olearia ilicifolia	1.70	119	Archeria traversii	0.65	158
Hebe subalpina	1.57	25	Chionochloa flavescens	0.63	8
Gaultheria rupestris	1.50	9	Dracophyllum longifolium	0.59	95
Carmichaelia grandiflora	1.38	12	TREES		
Coprosma foetidissima	1.24	508	Pseudopanax edgerleyi	5.75	31
Todea superba	1.21	158	Melicytus ramiflorus	5.07	119
Olearia arborescens	1.16	71	Griselinia littoralis	4.41	651
Blechnum capense	1.16	161	Carpodetus serratus	3.52	251
Polystichum vestitum	1.13	439	Hoheria glabrata	3.10	250
Coprosma ciliata	1.12	276	Aristotelia serrata	3.00	131
Aristotelia fruticosa	1.12	72	Fuchsia excorticata	2.70	268
Cyathea colensoi	1.11	75	Schefflera digitata	2.38	223
Hebe odora	1.10	16	Pseudopanax simplex	2.38	515
Dracophyllum menziesii	1.07	18	Pseudopanax arboreum	2.36	24
Coprosma rotundifolia	1.04	103	Pittosporum colensoi	1.94	40
Olearia avicenniaefolia	1.00	10	Myrsine australis	1.86	48
Pseudopanax anomalum	1.00	53	Weinmannia racemosa	1.78	449
Histiopteris incisa	0.98	83	Coprosma australis	1.75	30
Astelia cockaynei	0.96	387	Libocedrus bidwillii	1.70	28
Myrsine divaricata	0.93	326	Senecio bennettii	1.67	185
Olearia colensoi	0.93	59	Coprosma lucida	1.66	62
Podocarpus nivalis	0.93	29	Hedycarya arborea	1.59	69
Coprosma astonii	0.92	453	Pseudopanax crassifolium	1.49	323
Coprosma colensoi	0.91	217	Nothofagus menziesii	1.42	686
Pseudowintera colorata	0.91	442	Pseudopanax colensoi	1.38	344
Coprosma rugosa	0.88	32	Metrosideros umbellata	1.33	219
Coprosma rhamnoides	0.88	185	Pseudopanax lineare	1.24	190
Chionochloa conspicua	0.88	36	Podocarpus ferrugineus	1.15	142
Blechnum discolor	0.88	351	Dracophyllum traversii	1.13	66
Phyllocladus alpinus	0.84	114	Nothofagus cliffortioides	1.06	50
Coprosma pseudocuneata	0.82	299	Nothofagus fusca	1.05	120
Gahnia procera	0.80	10	Podocarpus dacrydioides	1.00	10
Dracophyllum uniflorum	0.79	30	Dacrydium cupressinum	0.97	70
Coprosma parviflora	0.76	55	Pennantia corymbosa	0.97	50
Neomyrtus pedunculata	0.75	74	Cyathea smithii	0.87	373
Cyathodes juniperina	0.75	13	Podocarpus hallii	0.77	237
Chionochloa pallens	0.73	36	Elaeocarpus hookerianus	0.75	46
Olearia lacunosa	0.72	28	Dacrydium biforme	0.71	92

are more stable. The most susceptible understorey is found in association D4, kamahi-pate-mahoe forest, which is the seral forest occurring at the lowest altitudes.

However, it is the overstorey susceptibility which is all important in the forest and scrub associations, as it is this which determines the ability of an association to regenerate and replace itself when exposed to browsing by deer. The forest associations which have the most susceptible overstorey are the four seral associations (D1 to D4), and associations A4 and C1 (Fig. 12). The order of susceptibility of these is as follows:

- D2 Tall lacebark-*Olearia-Polystichum* seral forest, of the upper mid-altitude talus slopes.
- D3 Fuchsia-wineberry-pate seral forest of the lower mid-altitude talus slopes.
- C1 Silver beech-pepperwood-waterfern forest of the terraces and gentle slopes at low altitudes.
- A4 Silver beech-*Myrsine-Polystichum* forest of the high altitude faces.
- D1 Short lacebark-*Olearia-Polystichum* seral forest of the high altitude talus slopes near the ecotone of forest and sub-alpine scrub.
- D4 Kamahi-pate-mahoe seral forest of the low altitude talus slopes.

Of these, only A4 is extensively distributed. The remainder have a more limited distribution, but, especially in the case of the four seral, D associations, are important hydrologically in that they occupy the areas which are most subject to accelerated erosion.

The least susceptible forest associations are B1 "mountain beech-*Phyllocladus* forest" and A3 "silver beech-*Archeria forest*". Both of these occur on stable sites — usually where the rock-weathering rate is slow.

The susceptibility of the sub-alpine scrub association, A1, is difficult to compare with the forest associations. Locally, on ridge tops, and where the scrub zone is rather narrow, it does appear to be susceptible, but elsewhere, especially where it occurs in a wide belt, it is probably the least susceptible of all the forest and scrub associations (Fig. 12).

(c) *Areas*

There is not a great deal of variation in susceptibility of the forest and scrubland between each of the six areas defined in Fig. 2. This is because the composition of the vegetation does not differ greatly from one area to another. The most susceptible areas are Block 5 (the Turnbull) and Block 2 (the upper Arawata-Waipara). The least susceptible areas are Block 4 (the lower Waiatoto) and Block 1 (the lower Arawata).

Recent Utilisation of the Vegetation

(a) Individual Species

Even though most species of trees, shrubs, and large herbs in the area show some sign of having been browsed, relatively few form the bulk of the fodder. The 26 species listed in Table 5 provide approximately 81% of the total browse, with the first seven; *Polystichum vestitum, Coprosma foetidissima, C. astonii,* broadleaf, *Myrsine divaricata,* kamahi, and *Pseudopanax simplex* providing 40%. It is noteworthy that seven *Coprosma* species provide almost 30% of the total fodder.

The percentages quoted above and in Table 5 are indicative only. They rely on

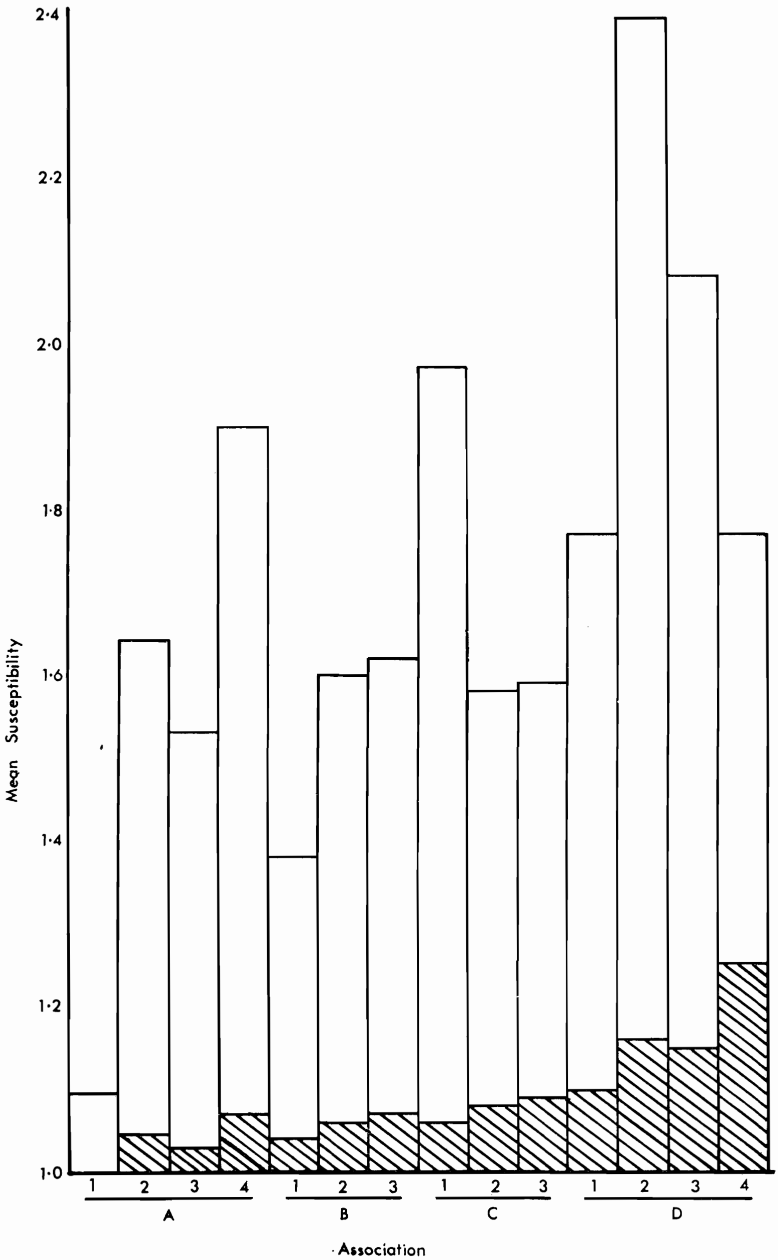

FIG. 12—Relative susceptibility of the associations to browsing by red deer. Understorey susceptibilities are shown hatched and overstorey open.

TABLE 5—The browse index and approximate percentage of total browse for the major fodder species. Species which provide less than 1% of total browse are not shown

SPECIES	BROWSE INDEX	% TOTAL BROWSE
Polystichum vestitum	528	8.63
Coprosma foetidissima	505	8.26
Coprosma astonii	409	6.69
Griselinia littoralis	333	5.44
Myrsine divaricata	287	4.69
Weinmannia racemosa	279	4.56
Pseudopanax simplex	251	4.10
Coprosma pseudocuneata	241	3.94
Coprosma ciliata	220	3.60
Astelia cockaynei	176	2.88
Coprosma rhamnoides	155	2.53
Cyathea smithii	152	2.49
Coprosma colensoi	144	2.35
Pseudopanax colensoi	143	2.34
Nothofagus menziesii	141	2.31
Todea superba	132	2.16
Dicksonia squarrosa	115	1.88
Pseudowintera colorata	105	1.72
Pseudopanax lineare	104	1.70
Microlaena avenacea	94	1.54
Hoheria glabrata	89	1.46
Fuchsia excorticata	87	1.42
Aristotelia fruticosa	81	1.32
Coprosma rotundifolia	66	1.08
Pseudopanax anomalum	66	1.08
Melicytus ramiflorus	65	1.06

a proportional relationship between the records of browsing, and the amount of fodder taken. This relationship does not necessarily always hold.

(b) Associations

The weighted percent browse frequency for each of the 12 indicator species is given for each association, in Table 6. The decreasing order of recent utilisation of the vegetation, derived from calculating a mean ranking order for the indicator species is given below:

C3 Silver beech-pepperwood-*Microlaena* forest
D1* Short lacebark-*Olearia-Polystichum* forest
A1* *Dracophyllum* sub-alpine scrub.

* These associations are not represented by a sufficient number of indicator species and hence the ranked position is somewhat inconclusive.

D3 Fuchsia-wineberry-pate forest
C1 Silver beech-pepperwood-waterfern forest
D2 Tall lacebark-*Olearia-Polystichum* forest
A4 Silver beech-*Myrsine-Polystichum* forest
C2 Silver beech-kamahi-*Blechnum* forest
B3 Silver beech-red beech-kamahi forest
B2 Silver beech-rata-kamahi forest
B1 Mountain beech-*Phyllocladus* forest
A2 Silver beech-*Senecio* forest
A3 Silver beech-*Archeria* forest
D4 Kamahi-pate-mahoe forest

TABLE 6—Weighted percent browse frequencies for 12 indicator species in each of 14 associations. The index has not been calculated where there is a low frequency of a species in an association. Weighted browse frequencies of greater than 300% reflect a high utilisation of epicormic shoots

INDICATOR SPECIES	ASSOCIATIONS													
	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	D4
Polystichum vestitum		100		162		150	100	186	136	190	50	174	200	127
Coprosma foetidissima		113	58	143	121	133	206		124				160	50
Coprosma astonii		74	59	129		69	119	137				116	131	
Griselinia littoralis		171		354	191	408	296							
Myrsine divaricata		74	60	131	92	103	166	207	100	73		170		
Weinmannia racemosa					93	130	140		245					170
Pseudopanax simplex		125	74	164	144	92	195		127					
Coprosma pseudocuneata	63	86		141	79	93						188		
Coprosma ciliata		55		131		93	88	165	36	40		146		
Astelia cockaynei		85	31	69	74	51	37		58					50
Coprosma rhamnoides						61	80		90	100				118
Cyathea smithii				72		57	31	45	61	30				42

The heaviest utilisation at present is in the lower mid slope and upper mid slope seral forest, and in the lower mid slope terraces. The utilisation appears to be least at high altitudes, in the sub-alpine scrub and upper forest, and at low levels, on the terraces and some seral areas. It appears that, at present, utilisation is least in the vicinity of both helicopter and foot hunting operations.

(c) Areas

The weighted percent browse frequency for the twelve indicator species is given for each of the six sub-divisions of the survey area in Table 7. The order of recent utilisation of the vegetation, derived by taking the mean of the ranking order of the indicator species follows:

Block 2 Upper Arawata-Waipara
3 Upper Waiatoto
1 Lower Arawata
4 Lower Waiatoto
6 Okuru
5 Turnbull

The three areas where utilisation is the least at present, the Turnbull, Okuru and lower Waiatoto, each have resident foot hunters. The upper Waiatoto also has a resident hunter but the area he covers is considerably larger than for the former three. The remaining two areas are not hunted as consistently.

TABLE 7—Weighted percent browse frequencies for 12 indicator species in each of six blocks of the survey area. Weighted browse frequencies of greater than 300% reflect a high utilisation of epicormic shoots

INDICATOR SPECIES	BLOCKS					
	1	2	3	4	5	6
Polystichum vestitum	154	230	153	62	69	86
Coprosma foetidissima	160	188	136	100	45	91
Coprosma astonii	76	171	96	87	36	63
Griselinia littoralis	259	525	200	508	57	189
Myrsine divaricata	104	171	107	139	14	56
Weinmannia racemosa	126	196	191	125	80	180
Pseudopanax simplex	169	200	114	83	30	47
Coprosma pseudocuneata	43	153	102	59	105	97
Coprosma ciliata	73	180	78	105	43	81
Astelia cockaynei	82	78	59	58	32	41
Coprosma rhamnoides	91	138	92	95	100	67
Cyathea smithii	28	54	52	5	20	56

Extent of Modification of the Vegetation

Twenty-four indicator species were chosen to represent the extent of modification of both the associations and of the sub-divisions of the survey area. The indicator species are listed in Tables 8 and 9. Indexes shown in each table for each indicator species were calculated from tier frequencies (*see* earlier section on "analysis"), and portray the frequency of the species inside the deer-accessible 0.3-1.8 m tier relative to the tiers below and above this tier. These indexes indicate the extent to which the forest understorey has been removed by red deer (and perhaps cattle in localised areas). High indexes indicate areas or associations where the vegetation has been heavily utilised and not had a chance to recover. Low indexes indicate areas or associations where utilisation has always been low or perhaps where there has been initial high utilisation but subsequent reduction in animal presence has allowed the vegetation to recover.

(a) *Associations*

The decreasing order of modification, derived from calculating a mean ranking order for the indicator species is given below:

C2 Silver beech-kamahi-*Blechnum* forest
C1 Silver beech-pepperwood-waterfern forest
C3 Silver beech-pepperwood-*Microlaena* forest
D2 Tall lacebark-*Olearia-Polystichum* forest
A4 Silver beech-*Myrsine-Polystichum* forest

TABLE 8—Extent of modification calculated for 12 tree and 11 shrub and herb indicator species in each of the 14 associations. The index has not been calculated where there is a low frequency of a species in an association. High indexes indicate high modification

INDICATOR SPECIES	ASSOCIATIONS													
	A1	A2	A3	A4	B1	B2	B3	C1	C2	C3	D1	D2	D3	D4
TREES														
Griselinia littoralis		3.79	1.94	6.62	1.91	3.71	2.56	10.17	11.00	7.83		>12.00	5.13	4.90
Carpodetus serratus				2.88		5.17	2.79	3.75	4.72	2.67			2.70	3.70
Hoheria glabrata		2.60		6.29			3.00	>15.00		3.50	1.75	2.93	1.83	1.20
Fuchsia excorticata				2.26		3.50	1.94	2.25	4.00	2.29			3.42	4.00
Schefflera digitata				5.00		6.00	1.90	3.33	2.72	4.00			1.46	2.17
Pseudopanax simplex		2.41	2.44	3.02	1.12	2.74	1.60	3.60	4.05	>8.00			1.58	
Weinmannia racemosa			7.00	3.88	1.17	1.56	1.13		2.35	2.58			3.00	3.10
Senecio bennettii		1.50	1.18	2.59	4.25	2.50						4.00		
Pseudopanax crassifolium			1.14	1.75		1.44	1.00	> 9.00	1.89	2.50				
Pseudopanax colensoi		1.32	0.90	1.82	1.14	1.81	1.14		1.88		1.21	2.50		
Nothofagus menziesii		1.09	1.07	1.22	0.77	1.97	1.11	1.59	2.97	5.17		2.75	1.58	>7.00
Metrosideros umbellata			1.17	1.00	0.62	2.41			3.50					
SHRUBS AND HERBS														
Asplenium bulbiferum									14.00	17.00			15.00	3.36
Olearia ilicifolia		2.00		1.85							1.09	1.39	5.50	
Coprosma foetidissima		1.00	1.06	1.43	1.29	1.17	1.11	2.00	1.51	1.33			1.20	1.50
Todea superba				1.25		1.08	1.04	1.70	1.60	1.23				0.89
Blechnum capense				1.20		1.13	1.04		1.44					
Polystichum vestitum		1.21		1.14		1.36	1.16	1.27	1.47	0.97	1.07	0.98	0.86	0.97
Coprosma ciliata		0.93		1.06		1.53	0.94	1.13	1.45	1.30		0.88	2.75	
Cyathea colensoi		0.78		1.50		1.12								
Coprosma rotundifolia									1.05	0.93				1.75
Astelia cockaynei	1.25	1.05	1.13	1.05	0.95	0.98	0.77	1.40	1.08					0.40
Myrsine divaricata		0.93	1.00	0.89	0.64	0.76	0.67	1.07	1.45	1.45		0.90		

D4 Kamahi-pate-mahoe forest
B2 Silver beech-rata-kamahi forest
D3 Fuchsia-wineberry-pate forest
A3 Silver beech-*Archeria* forest
B3 Silver beech-red beech-kamahi forest
A2 Silver beech-*Senecio* forest
D1 Short lacebark-*Olearia-Polystichum* forest
B1 Mountain beech-*Phyllocladus* forest.

TABLE 9—Extent of modification calculated for 12 tree and 12 shrub and herb indicator species in each of the six blocks of the survey area. High indexes indicate high modification

INDICATOR SPECIES	BLOCKS					
	1	2	3	4	5	6
TREES						
Griselinia littoralis	2.29	6.19	11.69	6.33	5.86	3.76
Carpodetus serratus	1.89	2.80	11.33	3.83	6.00	3.06
Hoheria glabrata	1.28	4.35	5.00	2.83	4.67	2.83
Fuchsia excorticata	2.30	3.38	5.58	2.92	2.80	1.81
Schefflera digitata	1.90	3.67	4.25	3.44	1.67	1.88
Pseudopanax simplex	1.45	2.44	3.48	3.25	3.55	3.24
Weinmannia racemosa	1.24	1.54	2.59	1.97	2.55	2.22
Senecio bennettii	1.73	1.36	2.42	1.75	1.05	1.60
Pseudopanax crassifolium	0.99	1.61	1.80	1.50	2.67	2.86
Pseudopanax colensoi	1.07	1.58	2.54	1.50	1.81	1.38
Nothofagus menziesii	1.11	1.02	1.95	2.80	2.50	1.36
Metrosideros umbellata	0.77	1.00	2.67	3.00	1.36	1.33
SHRUBS AND HERBS						
Asplenium bulbiferum	3.00	10.00	6.60	23.00	3.00	5.00
Olearia ilicifolia	1.50	1.84	2.00	2.20	1.57	1.07
Coprosma foetidissima	1.06	1.46	1.36	1.40	1.18	1.20
Todea superba	0.83	1.19	1.71	2.33	2.00	1.17
Blechnum capense	1.19	1.33	1.14	1.12	0.90	1.19
Polystichum vestitum	0.96	1.16	1.14	1.30	1.38	1.08
Coprosma ciliata	0.94	0.92	1.24	1.40	1.38	1.17
Aristotelia fruticosa	1.00	1.08	0.86	3.50	1.50	1.00
Cyathea colensoi	0.63	0.78	1.13	1.00	1.83	1.57
Coprosma rotundifolia	0.81	0.78	1.55	1.05	4.00	0.89
Astelia cockaynei	0.83	1.05	1.00	1.19	1.00	0.98
Myrsine divaricata	0.85	0.67	1.15	0.96	1.36	1.04

There are insufficient indicator species occurring in the sub-alpine scrub community, A1, to place it in the above ranking order. Field observations suggest that apart from localised sites, such as on main ridges, this association has not been greatly modified.

The most heavily modified associations are the terrace and lower slope silver beech forests and the seral mixed forest of the mid and lower slopes. In general, the least modified are the forests occurring in the vicinity of the timberline. The least modified of all is the mountain beech-*Phyllocladus* forest which occurs on shallow and infertile soils.

(b) *Areas*

The order of modification of the sub-divisions of the survey area, derived by ranking each indicator species in order of the indexes in Table 9 and then taking the mean of the ranking order for all species, is given below:

Block 3 Upper Waiatoto
4 Lower Waiatoto
5 Turnbull
2 Upper Arawata-Waipara
6 Okuru
1 Lower Arawata.

This shows that the forests and scrublands in the Waiatoto are the most severely depleted whereas those in the Okuru and lower Arawata are at present in the most satisfactory condition. Red deer have occupied the lower Arawata in numbers for a relatively short time (C. Challies, pers. comm.) and this would account for the good condition of the forests and scrublands here. However, the Okuru has had a long history of heavy red deer numbers (C. Challies, pers. comm.) and probably the relatively good condition of this catchment relates to Government hunting and later commercial venison recovery operations.

DISCUSSION

The purpose of the South Westland survey has been stated in the introduction (page 3) to be four-fold. The first requirement has been fully dealt with and the fourth does not require elaboration; the remaining two are discussed below.

The susceptibility, degree of modification, and present utilisation of the vegetation in the various forest and scrub associations and in the sub-divisions of the survey area have been discussed in the preceding section. The most susceptible associations are the seral ones and the most susceptible areas are the Turnbull and upper Arawata-Waipara. The forests most modified by red deer are those at low altitudes, especially in the Waiatoto, and the least modified are those at high altitudes. Present use of the vegetation tends to be greatest in the vicinity of he mid and lower-mid slopes, especially in seral associations and in the Arawata and upper Waiatoto catchments. It remains to compare briefly the survey area as a whole with other areas on the West Coast so that a certain degree of perspective can be brought into any decision on the management of this area, which may stem from consideration of this report.

Comparison is made with three other areas: Taramakau (Wardle and Hayward, 1970), Grey (Wardle, pers. comm.), and northern Fiordland (Wardle *et al.,* 1971). Five indicator species, common in all four areas have been chosen to show the degree of modification which has been induced by red deer and other ungulates. Indexes representing the frequency of each indicator species within the ungulate susceptible

0.3-1.8 m tier of vegetation relative to outside of it have been calculated for each area and are shown in Table 10. In each case high indexes represent high modification. The relative degree of modification for the four areas is derived by ranking each indicator species in the order of the index values and then taking the mean of the ranking order for the five species.

TABLE 10—Comparison of degree of modification of the survey area with three other survey areas: the Grey Catchment, Taramakau Catchment, and northern Fiordland. High values represent high modification.

SPECIES	GREY	TARAMAKAU	SOUTH WESTLAND	NORTH FIORDLAND
Fuchsia excorticata	13.00	4.00	2.70	2.31
Griselinia littoralis	9.07	3.57	4.41	2.33
Hoheria glabrata	4.21	4.00	3.10	1.75
Pseudopanax simplex	1.92	2.70	2.38	1.32
Weinmannia racemosa	1.81	2.13	1.78	1.02

The data indicate that the Grey and Taramakau have suffered by far the greatest modification. Northern Fiordland is by far the least modified. The south Westland survey area is considerably more modified than Fiordland but does not approach the degree of modification of the Grey or Taramakau.

Susceptibility of the forests to damage by opossums has not been considered. To date, opossums are of no importance in the animal-plant inter-relations of the area as numbers are too low and there are probably no breeding populations in the area. However, the frontal forests in particular have a high component of tree species such as kamahi which are highly susceptible to opossum damage and if opossums do become established severe deterioration in forest condition is to be expected.

The Influence of Venison Hunting on Forest and Scrubland Condition

Tier gaps have been used to indicate the extent to which the vegetation has been modified by the introduced ungulates, and browse indexes have been used to indicate current use. Evidence from tier gaps reveals that the vegetation has been most heavily modified at low altitudes while the forests and scrublands near timberline are the least modified. Evidence from browse indexes shows that current utilisation is greatest in the mid altitude zones and decreases both towards the timberline and towards the low level terraces. The relatively slight modification of the forests and scrublands at high altitudes could result from:

(a) the vegetation never having been subjected to high animal use, or

(b) response of the vegetation as a result of hunting pressure.

The main hunting pressure at these higher altitudes has been by helicopters during the last 5 or 6 yr. It is generally accepted that the growth potential of plants at high altitudes is relatively low. It is unlikely that significant response could have occurred over the short time that the helicopters have been operating and thus it is probable that the forests and scrublands at these high altitudes have never been subjected to high animal use. The role of the helicopters has therefore probably been to maintain low animal use in the upper forests and scrublands rather than to reduce it. However, evidence is inconclusive since the structure and composition of the original high altitude forests and scrublands can only be hypothesised and because there is some indication that the vegetation in some localised areas may have responded recently.

Shooters on foot have been in some valleys since at least 1947. They were initially Government hunters and later, during the last 10 yr, part-resident venison recovery hunters. Such venison hunting has largely been at low altitudes on and near the river terraces and lower slopes. Here the forest has been modified more by red deer than elsewhere. Now, however, red deer utilise the vegetation on these terraces less than they do the vegetation on the mid slopes, and on some areas spectacular recovery is evident. Even though the condition of the forest suggests an overall reduction of red deer pressure on these lower slopes and terraces, the extent varies from area to area. For instance, in the Okuru, Turnbull, and Waiatoto, which have part-resident shooters, the vegetation is not being utilised to the extent it is in the Arawata where shooting is more intermittent. Further, smaller shooting blocks such as the Okuru, Turnbull, and lower Waiatoto show improvement over the larger blocks, i.e., the upper Waiatoto.

Finally, the condition of the forests of the mid and lower-mid slopes, which is currently receiving the most intense browsing pressure, must be considered. It is appropriate to question whether these forests are subject to excessive pressure as a result of intense hunting at both high and low altitudes. A categorical answer to this question would again depend on an intricate knowledge of the structure and composition of these forests before the introduction of ungulates. Such knowledge does not exist. There is, however, sufficient evidence from other areas with similar vegetation, where animals are found in very low concentrations, to suggest that these mid-altitude forests are, at present, still in a satisfactory condition.

ACKNOWLEDGMENTS

We thank Mr K. Platt for his assistance in preparing photographs and diagrams for this report, Mr J. Copland and Mrs F. Coates for preparing the data for computer analysis, and Mr J. Holloway and Mrs J. Orwin for their criticism of the original draft. We also thank the following who were at one stage or another engaged on this survey: Messrs A. Leigh, P. Boswell, P. Beaumont, B. Manson, C. Barr, and C. Harman.

The assistance rendered by shooters and pilots in the venison recovery industry, by the local population of Haast, and by pilots of Tourist Air Travel Ltd, must also be acknowledged.

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